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COMPLETE SPECIFICATION

Improvements in or relating to Well-Flow Control Devices

We, SUN OIL COMPANY a Corporation organized under the laws of the State of New Jersey, United States of America, of 1608 Walnut Street, Philadelphia 3, Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a well-flow control device useful in the production of hydrocarbons from wells, and more particularly to a tool for enabling the production of well fluids from a plurality of formations penetrated by a well, or in other words, a multiple completion tool.

In well drilling practice, a single well may penetrate a plurality of formations which contain oil or gas. It is often desirable, in such cases, to complete the well for simultaneous production from more than one of the formations penetrated. The conventional procedure for doing this is to effect a dual completion, with the flow from a lower formation or zone taking place through the well tubing, and the flow from a higher formation or zone taking place through the annulus between the tubing and casing. Chokes are provided at the surface (well head) for separately regulating the rates of flow of the the two streams, to conform to the allowable production rates for each zone.

The foregoing method of dually completing a well is unsatisfactory, for several reasons. Production through the annulus is hazardous, due to the fact that the fluid stream tends to cause corrosion and erosion of the casing, thereby allowing the possibility of a blow-out, or subterranean loss of hydrocarbons to an upper formation. Also, when it becomes necessary to utilize gas lift to effect flow from the formations, the gas lift can be applied for only one zone at a time, and that only in an efficient manner; consequently, both production strata cannot be depleted simultaneously. In many cases, this results in large quantities of otherwise recoverable oil being left in the reservoirs. A further unsatisfactory condition arises when the annulus zone (the higher zone) begins to produce salt water. Due to inefficient flow in the annulus, salt water accumulates therein, and thus loads up the well and stops the oil flow. Production from that zone then is generally abandoned. Later attempts to produce from such zone, after the other zone has become depleted, often fail to restore the production. Still another drawback in conventional dual completions is that paraffin often tends to accumulate in the annulus; such accumulations are difficult to remove.

According to the present invention there is provided a well-flow control device adapted to be positioned in well tubing for controlling the flow of a fluid into the tubing from a producing formation, comprising an outer housing having an opening for communication with the interior of said tubing; means carried by the housing for retrievably locking the same at a predetermined location in the tubing, packing means for closing the annular space between the housing and tubing above said opening, said housing having an internal flow channel extending upwardly from its opening; an inner housing having an internal fluid flow passage for communication with said flow channel and with the interior of said tubing above said packing means; means carried by the inner housing for retrievably fastening the same in position in said outer housing but allowing the withdrawal of the inner housing without the device from the well. The opening may either be across the lower end of the outer housing or be a side part,

According to another aspect of the present invention provides a flow control device comprising a main flow control device and an auxiliary flow control device which can be removed from the main flow control device without removing the latter from the well, for a well flow conductor having a longitudinal flow passage and a first lateral port communicating with the flow passage intermediate the ends thereof, the main flow control device including: an elongate mandrel positioned in the well flow conductor and provided with an internal flow passage for communicating at its upper end with the flow passage in the well flow conductor and with a second lateral port intermediate the ends of the mandrel for communicating with the exterior of the mandrel and said internal flow passage and with said first lateral port; seal means carried by the mandrel for sealing between the well flow conductor and the mandrel below said lateral ports, said mandrel having an aperture for communicating with the flow passage of the well flow conductor below the seal means; means carried by the mandrel permitting flow in one direction only into the internal flow passage of the mandrel through said second lateral port and said aperture; the auxiliary flow control device being releasably securable to the upper end of the mandrel and having means extending into said internal flow passage providing with said internal flow passage, when the auxiliary flow control device is secured to the main flow control device, a first flow passage communicating with said second lateral port of the mandrel and opening upwardly into the well flow conductor above said first lateral port and providing a second flow passage communicating with said aperture and opening upwardly into the well flow conductor.

An object of this invention is to provide new and improved means for completing a well for simultaneous production from two of more zones (a well known as a "multiple completion"), while avoiding the disadvantages of conventional dual completions, such as those described above. The construction of the device or tool of the present invention, while avoiding the disadvantages of conventional dual completions, provides additional advantages. Among the latter may be mentioned the elimination of any possibility of clogging of the chokes by foreign matter, the elimination of any possibility of erosion of tool parts by high-velocity flow through the chokes, and the improved corrosion resistance of the check valves used in the tool.

Operation of a well according to the invention involves the use of a two-part or two-piece flow control device, hereinafter described, which is positioned in the well tubing adjacent one of the producing formations Fluids from the formations pass as separate streams through the flow control device and thereafter commingle in the tubing, and flow from the tubing at the well head as at single stream. The flow control device contains choke means which, in addition to its normal production-limiting function, causes a fluid stream from a zone of high pressure to undergo a sharp pressure drop prior to commingling with another stream. The resulting pressure reduction causes or facilitates the flow of fluids from one or more of the zones of relatively low pressure.

The two-piece flow control device comprises: (1) an outer housing, which is retrievably locked at a predetermined location in the tubing (by means of a landing nipple provided in the tubing); and (2) an inner housing which is retrievably fastened in the outer housing. The outerhousing has two separate internal flow channels which are adapted to communicate, respectively, with the two producing zones or formations, and this housing mounts a check valve in each channel. The inner housing provides two separate internal fluid flow passages which communicate, respectively, with the flow channels of the outer housing, and mounted in the upper end of this inner housing are two chokes one for each fluid flow passage. For controlling the flow of fluid from a single formation or zone, the inner housing would be provided with only one fluid flow passage, and one choke.

A detailed description of the invention follows, taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a schematic representation of the device or tool of the invention in position in a well;

Figs. 2A, 2B, 2C, and 2D together constitute Fig. 2, which is a detailed view, partly in section, of the tool of the invention in its operative position, but dissociated from a well;

Fig. 3 (in two parts) is a partial view similar to Fig. 2, but showing the inner housing in its unlocked or pulling position; and

Figs. 4A, 4B, 4C, and 4D together constitute Fig. 4, which is a view similar to Fig 2 but illustrating another embodiment of the invention.

Referring first to Fig. 1, which is a somewhat schematic representation illustrating the invention, a well has a casing 10 which has been cemented in place in the usual manner. The well traverses two production zones (producing formations), illustrated as an upper Zone A and a lower Zone B, which may be either gas or oil formations. The casing has been perforated for production from both zones, as illustrated by perforations 11 adjacent Zone A and perforations 12 12 adjacent Zone B. A tubing string 13 is positioned in the casing, and the annulus therebetween is closed off near the bottom of the

tubing by means of packer 14, which latter prevents communication between the two zones by way of the casing-tubing annulus. The tubing carries a landing nipple assembly 15 (to be described in detail hereinafter) in which the outer assembly 16 of the flow control device is retrievably locked, in a manner to be described hereinafter. The landing nipple assembly 15 is positioned adjacent Zone A, and contains ports 17 (located above packer 14, and communicating with the casing-tubing annulus) for receiving fluid from this zone.

It should be apparent that another packer (not shown), similar to packer 14, would be provided above ports 17, to seal the casing-tubing annulus above these ports and to prevent the flow of fluid from Zone A to the surface by way of this annulus. Suitable packers for these casing-tubing annulus seals or closures are described in detail in United States Patent No. 3,022, 828, dated February 27, 1962.

The outer assembly or housing 16, which may be located and locked in nipple assembly 15 by means of wire line equipment, forms an annulus 18 with the landing nipple assembly 15. This outer housing contains upper side ports 19 for passage of fluid from Zone A, and lower side ports 20 for passage of fluid from Zone B. Ports 17 and 19 communicate with annulus 18, and ports 20 communicate with the interior of the tubing 13. Upper packing means 21, positioned in annulus 18 above ports 19, and lower packing means 22, positioned in annulus 18 between ports 19 and 20, prevent fluid flow along the annulus 18 and force the fluid from the upper Zone A to flow through ports 19 into housing 16; packing means 22 also forces the fluid from the lower Zone B to flow through ports 20 into housing 16.

The upper side ports 19 define one end of a first internal flow channel which extends upwardly (in outer housing 16) from such side ports. A resilient sleeve-type check valve 23 (illustrated schematically in Fig. 1, but to be described more completely in connection with Fig. 2) is positioned in this flow channel, to prevent backflow of fluid toward the upper Zone A. The lower side ports 20 define one end of a second internal flow channel which extends upwardly (in housing 16) from such side ports. A resilient sleeve-type check valve 24 is positioned in this second flow channel, to prevent backflow of fluid toward the lower Zone B.

The lower end of outer housing 16 has therein an equalizing valve member 25 which is normally in a position such as to seal the lower end of this housing. The lower end of tubing 13, below packer 14, is open or is ported, as indicated by dotted lines 27 in Fig. 1, so that fluid from Zone B can flow through casing perforations 12 and into the interior of tubing 13, as indicated by the arrows 26, and thence can flow upwardly in the tubing and through housing ports 20 and past check valve 24 into the interior of housing 16. The series of arrows 26 thus indicates the lower zone flow path.

A so-called "blast joint" 28, providing a special abrasion-resistant surface, couples the lower end of nipple assembly 15 to the adjacent section of tubing 13, in a region horizontally aligned with casing perforations 11. A flow coupling 29 couples the upper end of nipple assembly 15 to the adjacent section of tubing 13. Thus, it may be seen that the landing nipple assembly 15 in effect serves as a special section of tubing inserted in the tubing string. Fluid from Zone A flows through casing perforations 11 and into the casing-tubing annulus, as indicated by the arrows 30, and thence upwardly in this annulus and through tubing ports 17 and housing ports 19 and past check valve 23 into the interior of housing 16. The series of arrows 30 thus indicates the upper zone flow path.

Summarizing the description thus far, with the outer housing 16 run and locked in place in nipple assembly 15, production from each zone can separately enter the housing, but communication between zones is prevented by the resilient check valves 23 and 24.

An inner housing 31, which may be termed an orifice head assembly, is retrievably fastened in position in the outer housing 16, in a manner to be fully described hereinafter. The inner housing is run separately from outer housing 16, by means of wire line equipment, and seats in the running neck of the outer housing; this will become clearer as the description proceeds. The inner housing 31 forms an annulus 32 with the outer housing or assembly 16. Upper packing means 33, carried by housing 31, schematically seals annulus 32 above housing ports 19, while lower packing means 34, also carried by housing 31, seals annulus 32 below ports 19. The inner housing or orifice head assembly 31 has two separate internal fluid flow passages, each of which terminates in a respective choke bean mounted at the upper end of this assembly.

More specifically, one fluid flow passage (denoted generally by numeral 35) opens into or communicates with the interior of outer housing 16 below the lower packing means 34, as indicated by dotted lines 36. Passage 35 extends upwardly through housing 31 and terminates in a choke means (carbide-faced choke bean) 37 at the upper end of housing 31. Passage 35 thus forms a continuation of the lower Zone B flow path 26, and the production rate from the lower Zone B is controlled by choke 37.

The other of the two fluid flow passages (in inner housing 31) previously referred to

communicates with the annulus 32, as schematically illustrated at 38, extends upwardly through housing 31 (separately from passage 35), and terminates in a choke means (carbide-faced choke bean) 39 at the upper end of housing 31. Chokes 37 and 39 are parallel to each other, and they are both located at and mounted in the top of housing 31. It may be seen that fluid from the upper Zone A flows past check valve 23 into the annulus 32. The last-mentioned flow passage forms a continuation of the upper Zone A flow path 30, and the production rate from the upper Zone A is controlled by choke 39.

It may be seen, from the foregoing, that separation of the production from the two Zones A and B is maintained prior to the chokes 37 and 39, so that the initial point of commingling of the two streams is just downstream from the choke beans 37 and 39, i.e. just above these two beans. Above or downstream from the choke beans, the two fluid streams commingle, and commingled flow to the surface takes place upwardly through the tubing string 13.

The pressure at the point of commingling (just downstream from the choke beans 37 and 39), which is a function of gas-liquid ratio, production rate, and tubing size, need be only that required to lift the combined (commingled) fluids to the surface. That is to say, energy is released at this point of commingling. It is therefore possible, in many wells, for the weaker (pressure-wise) zone to enter the tubing, even though its reservoir pressure may be considerably lower than the other.

In order to determine how much each zone contributes to the combined or commingled flow stream, a separate test of one zone can first be made, by blanking off production from the other with a plugged choke bean. This determines the production rate from said one zone. A test may then be made with both zones (sands) producing, the increase in production being credited to the zone not tested separately. In order to change chokes to make such tests, or to change production chokes should this become necessary, all that is required, with the tool of this invention, is to pull the inner housing (orifice head assembly) 31, by means of wire line equipment, while leaving the outer housing 16 in place. This is a very simple wire-line operation, a routine operation in the hands of an experienced wire-line operator, and thus one which requires a minimum amount of time. When the inner housing 31 is pulled in this manner, the outer housing 16 remains in the well, separation between the zones then being maintained by means of check valves 23 and 24, and packers 21, 22, and 14.

It is pointed out that both of the chokes 37 and 39 are in the same single assembly (to wit, housing 31). It is often desirable to change the chokes controlling each of the two zones, and to do so at the same time. Utilizing the construction of this invention, this can be accomplished in one operation, by pulling the housing 31 from the well.

It is also pointed out that when the outer housing 16 is left in the well in this manner, while pulling the inner housing 31, nothing that contacts the tubing is moved or disturbed, which means that there can be no possible damage to the tubing. This feature is quite important, particularly when plastic-coated tubing is employed in the well.

When the two chokes are mounted parallel to each other and at the top of the tool, as described, the flow from the chokes is vertically upward and is unobstructed, and there are no metal surfaces exposed to the flow from the chokes (and therefore, there are no such surfaces subject to rapid erosion, with consequent failure of the tool).

Fig. 2 is a detailed view, partly in section, of the tool of the present invention, both the outer and inner housings being illustrated in their operative positions, but the casing and well being omitted for simplicity. The conformity of Figs. 1 and 2 will become apparent as the description proceeds.

The elongated outer housing 16 carries at its top a running neck 40 in which the inner housing or orifice head assembly 31 seats. This running neck is integral with or fixedly secured to the outer housing 16, this housing also having a pulling neck 41 which is slidable thereon. Latching or locking means, comprising a plurality of spaced dogs 42 which are pivotally attached to pulling neck 41, are provided for securing the outer housing 16 in place in the upper or landing nipple portion 15a of a three-part landing nipple assembly 15, which latter may be, for example, an "Otis Type S Side-Door Choke Landing Nipple Assembly". The landing nipple assembly 15 comprises the landing nipple portion 15a, previously referred to, a ported collar 15b threadedly secured at its upper end to the lower end of portion 15a, and a polish nipple 15c threadedly secured at its upper end to the lower end of collar 15b. The portion 15c is provided with threads at its lower end, for coupling to lower tubing sections (not shown) of conventional construction, while portion 15a is threadedly connected at its upper end to a conventional tubing collar 43, and by means of this latter collar to upper tubing sections (not shown) of conventional construction. The landing nipple assembly 15 is located in the tubing string as to be adjacent to Zone A (see Fig. 1).

The dogs 42 are pivotally suspended from pulling neck 41, by means of an inwardly-extending cylindrical boss at the lower end of neck 41 which fits into a matching recess provided at the upper end of each of the dogs

42. The inner surfaces of these dogs are positioned against a beveled or tapered portion of the body of housing 16, as indicated at 44, this tapered portion increasing in diameter toward its lower end. The dogs 42 move vertically with neck 41, so that the inner surfaces of the dogs are slidable on the tapered surface 44; therefore, downward movement of the dogs relative to the tapered surface 44 causes the dogs to move outwardly. Dogs 42 are adapted to enter a cylindrical recess 45 of limited length provided in the landing nipple 15a. The latching or locking means here described is quite similar to that disclosed in Miller U.S. Patent No. 2,673,614, dated March 30, 1954.

Below dogs 42, the outer housing 16 carries a set of spring-loaded keys 46 which are mounted around the housing. These keys resemble an ordinary door key and are "profiled" to match with an identically-shaped locating recess 47 machined within the bore of the landing nipple portion 15a.

Before proceeding to a description of the flow controlling portions of the tool, the operation of the landing and locking means for the outer assembly or housing, which means has just been described) will first be explained. This landing and locking means comprises means for retrievably locking the outer housing at a predetermined location in the tubing. When the outer housing 16 is ready to be inserted into the well, the same is lowered into well tubing 13 (see Fig. 1) on a wire line, by means of a suitable running tool which attaches to running neck 40. This running tool may be of a type known in the art. The running tool (not shown) grips the housing 16 in such a way that running neck 40 and pulling neck 41 are held together. In other words, the upper part of the pulling neck 41 is held higher than shown on the running neck 40 by the running tool, as the housing is lowered. This means that the dogs 42 will ride higher on the tapered portion 44 than shown in Fig. 2.

The housing with keys 46 will pass downwardly until it reaches landing nipple portion 15a, which has a recess 47 such as to match keys 46. When the outer housing 16 reaches this landing nipple portion, the spring-loaded keys 46 "select" the matching recess 47, and move outwardly into this identically-shaped recess. This prevents further lowering of the outer housing. The wire line is then manipulated in such a way that the "jars", which are run just above the running tool, impart a downward hammer action to the housing. This shears a pin within the running tool and frees the pulling neck 41 for movement downwardly, allowing the dogs 42 to fall freely and move down the tapered portion 44, into the locking position shown in Fig. 2. Upward jaring then drives the tapered portion 44 upwardly, sliding this portion upwardly against the dogs 42 and forcing them into locking position in recess 45, as shown in Fig. 2. This locks the outer housing 16 fast in landing nipple portion 15a. Additional parring upwardly then releases the running tool, which is withdrawn from the well on the wire line.

The outer housing 16 ordinarily remains in position in the well at all times, and does not ordinarily need to be removed therefrom. However, when removal thereof is necessary (for example, in order to repair or replace the check valves), the outer housing may be pulled from the well by means of a pulling tool known in the art.

The landing, or locating, and locking mechanism just described is entirely conventional, so further description thereof does not appear to be necessary. For further details of such mechanism, reference may be had to the Miller patent, previously mentioned.

The running neck 40 is hollow, as is the outer housing 16, so that a continuous bore extends from end to end (longitudinally) of this outer housing. This bore is open at its upper or running neck end, but is closed at its lower end by means of a plug or equalizing valve member 25 which carries a sealing O—ring 48 in a groove in its outer surface; O—ring 48 makes sealing contact with the inner cylindrical wall of housing 16. Member 25 is ordinarily maintained in position at the lower end of housing 16, by means of a shear pin 49 which extends through the wall of housing 16 into member 25. The normal position of member 25 (as maintained by shear pin 49) is such that O—ring 48 is located above a plurality of radially-extending ports 50 which extend through the side wall of housing 16. When it is desired to withdraw outer housing 16 from the well, a "jar" and pulling tool are lowered into the tubing by means of a wire line, and manipulated to drive member 25 downwardly so as to shear the pin 49. When pin 49 is so sheared, member 25 moves downwardly within the housing 16 a distance such that O-ring 48 moves below ports 50, thereby opening communication (by way of ports 50) between the lower end of housing 16 and the surrounding fluid. This causes an equalization of pressures between the interior and exterior of housing 16, so that housing 16 can readily move upwardly in the well, once this housing is unlocked from the landing nipple portion.

In a region of outer housing 16 above member 25, a plurality of narrow elongated slots 20 (elongated in the circumferential direction of the housing) are cut through the outer wall of this housing. These slots are made narrow (in the vertical direction) to serves as screened side ports in the wall of the outer housing; the width (vertical) dimension of these slots will be further referred to hereinafter.

Fluid from the lower Zone B (Fig. 1), which enters the casing by way of perforations 12 and which flows upwardly through tubing 13 from the lower open end thereof or from ports provided in the tubing, can flow around the outside of outer housing 16 (at the lower end of this housing) and can flow into the interior of this housing by way of the housing side ports 20. A separate internal flow channel extends upwardly from the side ports 20. This flow channel includes an annular channel 51 in outer housing 16 and a plurality of inclined bores 52, which latter communicate at their lower ends with the upper end of channel 51 and at their upper ends with the interior of housing 16.

A resilient sleeve-type check valve member 24 is positioned in annular channel 51, to prevent back-flow of fluid through side ports 20. Any downward flow of fluid in channel 51 causes the upper edge of valve 24 to move outwardly against the radially-outer side of this channel, thereby covering or sealing off ports 20 from radially-outward flow. The check valve should be constructed of a tough material, such as "Neoprene" (Registered Trade Mark), "Urethane", "Teflon" (Registered Trade Mark), etc. which is unaffected by well fluids and which has sufficient flexibility for movement of the upper edge therof outwardly against the outer side of channel 51. Such material is highly resistant to abrasion by sand or other materials which may be present in the well fluids, and is also highly resistant to corrosion by corrosive liquids which may be present in such fluids. It is pointed out that resilient check valves of this type have been proven in service to have a long life, in fact very long as compared to other types of check valves, such as metal ball-check valves.

Above bores 52, the outer housing 16 carries a packing member 22 which engages the inner cylindrical wall of polish nipple 15c, to seal off the annulus between the landing nipple assembly 15 and the outer housing 16.

Above packing member 22 the ported collar 15b is provided with a plurality of radially-extending ports 17 which provide communication between the casing-tubing annulus (see Fig. 1) and the nipple assembly-outer housing annulus 18. Fluid from the upper Zone A, which flows into the casing-tubing annulus by way of perforations 11 (Fig. 1), flows through ports 17 into annulus 18. In the vicinity of ports 17, a plurality of narrow elongated slots 19 (elongated in the circumferential direction of the housing) are cut through the outer wall of outer housing 16. These slots are made narrow (in the vertical direction) to serve as screened side ports in the wall of the outer housing; the width (vertical) dimension of these slots will be further referred to hereinafter.

A separate integral flow channel extends upwardly from the side ports 19. This flow channel includes an annular channel 53 in outer housing 16 and a plurality of inclined bores 54, which latter communicate at their lower ends with the upper end of channel 53 and at their upper ends with the interior of outer housing 16, in the region of annulus 32.

A resilient sleeve-type check valve member 23, exactly similar in construction and material to valve member 24, is positioned in annular channel 53, to prevent backflow of fluid through side ports 19.

It may be seen that valve members 23 and 24 are both carried by outer housing 16, and are thus both maintained in position even when inner housing (orifice head assembly) 31 is pulled or removed from the well, the outer housing 16 remaining in the well at this time. Therefore, separation between the two producing zones is maintained at all times, even when the chokes are being replaced for test or repair purposes.

Above ports 19, the outer housing 16 carries a packing member 21 which engages the inner cylindrical wall of landing nipple portion 15a, to seal off the annulus between the landing nipple assembly 15 and the outer housing 16.

The inner housing or orifice head assembly 31 is a member separate from outer housing 16, and is retrievably fastened in position in such outer housing in a manner to be fully described hereinafter. Housing or assembly 31 comprises an upper substantially cylindrical main body portion 55 to which is secured, as by means of weldment 56, a prong-like axial downwardly-extending tubular member 57. The interior of tubular member 57 provides the fluid flow passage 35, which was previously referred to in connection with Fig. 1. When inner housing (orifice head assembly) 31 is in position in outer housing 16, tube 57 extends downwardly within outer housing 16, this tube being smaller in outside diameter than the inside diameter of housing 16, thereby to leave an annular space 32 between this tube (portion of inner housing 31) and outer housing 16. Tube 57 extends down to a point below the ports 54, and the lower end of this tube, below the ports 54 in housing 16, is enlarged somewhat in diameter and carries a pair of O-rings 34, to provide a seal between the outer surface of this tube and the inner wall of housing 16. O-rings 34 comprise a packing means which delimits the lower end of annulus 32, and seals annulus 32 below ports 19 and 54.

The extreme lower tip of tube 57 is tapered, or made somewhat frusto-conical in configuration, to facilitate or ensure the entry of the lower end of this tube into the upper end of running neck 40 of outer housing 16, when the inner housing 31 is being run into the outer housing 16. At its tip,

tube 57 is provided with a plurality of inclined bores 58, which communicate at their lower ends with the interior of housing 16 below packing means 34 and at their upper ends with the interior of tube 57, i.e. with the fluid flow passage 35. It should therefore be apparent that the internal fluid flow passage 35 (interior of tube 57) communicates (by way of bores 58) with the outer housing flow channel 51, 52. Fluid from the lower Zone B thus flows into tube 57 by way of side ports 20, channel 51 (past valve 24), bores 52, the interior of outer housing 16, and bores 58. This fluid flows upwardly inside tube 57 (passage 35).

At weldment 56, an offset channel 59 is coupled to the upper end of tube 57, channel 59 leading upwardly through the body 55 of the inner housing (orifice head assembly) to the lower end of a replaceable choke 37 having a carbide-faced throat 60. Choke 37, through which all the fluid from the lower zone thus passes, controls the rate of flow of this fluid. Choke 37, whose throat or passage 60 extends longitudinally of body 55, is held in position at the upper end of inner housing 31 by means of a threaded nut 61, which has an axial opening therethrough and which threads into a tapped aperture at the upper end of housing 31.

In the body portion 55 of inner housing 31, there is provided a short sleeve 62 which surrounds but is space from tube 57. This sleeve carries a pair of O-rings 33, to provide a seal between the outer surface of the sleeve and the inner wall of the running neck 40 of outer housing 16. In effect, then, the orifice head assembly 31 seats in the running neck 40 of the outer housing 16. The annular space provided between tube 57 and sleeve 62 communicates at one end with annulus 32 (of outer housing 16), and at its opposite end with an annular chamber 63 (provided by the body of inner housing 31) which surrounds channel 59.

To the upper end of chamber 63, a channel 64 is coupled, channel 64 leading upwardly through the body 55 of the inner housing (orifice head assembly) to the lower end of a replaceable choke 39 having a carbide-faced throat 65. Choke 39, whose throat or passage 65 extends longitudinally of body 55, is held in position at the upper end of inner housing 31 (and parallel to choke 37) by means of a threaded nut 66, which has an axial opening therethrough and which threads into a tapped aperture at the upper end of housing 31.

Fluid from the upper Zone A flows into channel 64 by way of ports 17, annulus 18, side ports 19, channel 53 (past valve 23), bores 54, annulus 32 (in which it flows upwardly), the annular space within sleeve 62, and annular chamber 63. Choke 39, through which all of the fluid from the upper zone passes, control the rate of flow of this fluid.

The fluids from the two Zones A and B are mixed or commingled above (i.e., downstream of) the two chokes 37 and 39 (see Fig. 1). This process may be termed subsurface commingling.

It has previously been stated that the chokes 37 and 39 are carbide-faced; thus, they are made of an extremely hard material and have long life. Moreover, they are of standard size, so that predetermined producing rates for the zones can be set.

The width (i.e., the vertical dimension) of the entrance slots 20 is less than the diameter of choke passage 60 in the lower zone choke 37. Likewise, the width (i.e., the vertical dimension) of the entrance slots 19 is less than the diameter of choke passage 65 in the upper zone choke 39. This feature provides a screening effect for the inlet ports of the tool. Particles large enough to stop up or clog the chokes are prevented from entering the tool and then finding their way to the chokes, due to the smal size of the entrance slots at the inlet ports.

It has been stated previously that the inner housing 31 (orifice head assembly) is a separate member, which is retrievably fastened in position in the outer housing 16. The orifice head assembly 31 is run and pulled independently of the outer housing 16. The structure for retrievably fastening assembly 31 in position will now be described.

The running neck 40 of outer housing 16 has a diameter greater than does the main body of this housing, and at the junction between this neck and the housing main body there is provided a beveled (frusto-conical) surface 67 which extends outwardly and upwardly with respect to the housing body. A plurality of elongated fingers 68, together forming a collet 69, are mounted at their upper ends in a circumferential recess 70 near the upper end of the body portion 55 of the orifice head assembly 31. Thus, the fingers 68 are rather rigidly fastened to body portion 55 of assembly 31. At their lower ends, fingers 68 have inwardly and downwardly-extending tapered surfaces 71 (complementary to the surface 67) which, in the locked position illustrated in Fig. 2, fit under the surface 67 of the running neck 40, to lock the inner housing 31 in position in the outer housing 16, i.e., to fasten inner housing 31 in position and prevent upward movement of the latter in outer housing 16. It will be remembered that fingers 68 are rigidly secured to the inner housing body 55.

Chokes 37 and 39, and retaining or mounting nuts 61 and 66, are positioned in the running neck or orifice head 31, which is integral with or fixedly secured to the main body 55 of housing 31.

The orifice head assembly 31 carries a

pulling neck 72 which is slidable on the main body 55 of this assembly, so that it is slidable with respect to the fingers 68, secured to such body. Integral with the pulling neck 72 is a locking sleeve 73 which surrounds the fingers 68 and, when driven down to the position illustrated in Fig. 2 prevents outward movement of the lower ends of these fingers, and maintains the finger surfaces 71 locked under the surface 67 of running neck 40. That is to say, sleeve 73 serves as a locking means for the collet 69.

When the locking sleeve 73 is in the "up" or "running" or "pulling" or "unfastened" or "unlocked" position illustrated in Fig. 3, that is, when this sleeve is riding on the upper taper of the collet fingers, the lower ends of the collet fingers (i.e., surfaces 71) are free to move outwardly from under the running neck beveled surface 67, thus permitting vertical movement of inner housing 31 with respect to the outer housing 16.

The orifice head assembly 31 is run and pulled independently of the outer housing 16. As previously described, the tube 57 is adapted to fit into the bore of the outer housing 16, and when the tube is in its ultimate or operating position, the O-rings 34 provide a seal between the outer surface of this tube and the inner wall of housing 16, below the outer housing ports 54. Also, in the ultimate position of assembly 31, sleeve 62 of this assembly seats in the outer housing running neck 40.

When going into the hole with the orifice head assembly 31 (assuming that the outer housing 16 has previously been locked in position in the hole), the locking sleeve 73 is held in the "up" position (i.e., in the position illustrated in Fig. 3, with this sleeve riding on the upper taper of the fingers 68 which comprise collet 69) by the running tool (not shown), which is used on a wire line. When the running neck 40 of the outer housing 16 is reached by the collet fingers 68, these fingers spring out and pass over this running neck. There is enough flexibility in these fingers (which are rigidly secured only at their upper ends to the inner housing body portion 55, as previously described) to allow passing over running neck 40. Sleeve 73 is at this time in a position such as to allow this outward movement of the lower end of finger 68.

When the collet fingers have passed below the beveled surface 67 at the lower end of neck 40, the fingers retract (i.e., move inwardly) and fit under this neck. By suitable manipulation of the wire line equipment, the locking sleeve 73 is then driven downwardly, to the position illustrated in Fig. 2, to fasten or lock the orifice head assembly in position in outer housing 16. In the Fig. 2 position, the lower end of sleeve 73 closely surrounds the lower ends of fingers 68 and causes surfaces 71 thereof to engage beveled surface 67 of running neck 40.

In the locked or operative position illustrated in Fig. 2, the O—rings 34 of the orifice head assembly 31 are in sealing position, and the O-rings 33 of this assembly are also in sealing position, as described hereinabove. Then, flow from the two zones or producing formations takes place independently in the manner previously described, with commingling of the two streams downstream of or above the production zone chokes 37 and 39.

Once the running and locking procedure for the orifice head assembly 31 has been completed in the manner just described, the collet lock 69 can be released only by running a pulling tool (on a wire line) and jarring up on the pulling neck 72 of the orifice head assembly (which moves sleeve 73 upwardly). When this is done, the orifice head assembly 31 can be pulled out of the outer housing 16, which latter remains in position in the hole. Thus, the check valves 23 and 24 (which are secured to outer housing 16, as previously described) remain in position under these circumstances, maintaining separation between the two producing zones at all times (it will be understood that packers 21, 22, and 14, which also remain in position, contribute to this result).

As previously mentioned, a separate test of one zone can be made whenever desired, by blanking off production from the other with a plugged choke bean. It will be remembered that this, with another production test, enables the operator to determine how much each of the two zones contributes to the total flow stream. This test procedure requires two round trips with the orifice head assembly 31. However, the collet lock on the orifice head, the design of the lower end of orifice tube 57, and the design of the running tool, which acts as a certalizer, combine to make this a very simple wire-line operation.

Recapitulating, the tool of this invention offers the major advantages now to be presented. It conserves energy, by allowing the surplus energy from one zone to lift fluid from a weaker zone to the surface; it opens the way for simple, relatively inexpensive concentric duals that can be produced to depletion without the disadvantages of casing-tubing annulus flow; it increases the daily production rate (where one zone is deficient); it increases the total recovery; and, it reduces cost.

The multiple completion tool of this invention (which may be thought of as a dual flow choke, since production from two producing zones or formations takes place through respective chokes, prior to commingling) can be modified for use in single zone completions, that is, in wells producing

from a single zone. In such a case, it would be used as a so-called bottomhole choke, with a single carbide bean (choke bean) contained in the orifice head assembly. In many wells, this would enable elimination of the conventional surface gas heater, and production gains could be made.

Reference should now be had to Fig. 4, which is a view similar to Fig. 2 but illustrating the modified construction. In this figure, elements the same as those of Fig. 2 are denoted by the same reference numerals. In Fig. 4, the landing nipple assembly includes only the landing nipple portion 15a, the ported collar 15b and the polish nipple 15c of Fig. 2 being omitted. In Fig. 4, the landing nipple portion 15a is made somewhat longer than in Fig. 2, and below the "key" recess 47 it is provided with a polished cylindrical wall, to enable a seal to be made by the packing means 22 which is carried by the outer housing 16. The lower end of landing nipple portion 15a is provided with male threads 74 which enable the lower end of this nipple portion to be coupled to the adjacent section of the tubing (not shown). Packing means 22 seals the annulus 18 above threads 74, and prevents the flow of fluid upwardly through such annulus.

The equalizing valve 25 of Fig. 2 is not utilized in Fig. 4, so that in Fig. 4 the lower end of the outer housing 16 opens directly into the interior of the tubing string. Therefore, fluid from the producing formation or zone (which first flows through casing perforations into the casing-tubing annulus and thence into the tubing by way of ports therein or through the lower open end thereof, as previously described in connection with Figs. 1 and 2) flows fro mthe interior of the tubing vertically upward into the lower end of the outer housing 16 of the tool, and thence vertically upward in such housing, through the longitudinal bore therein. Packing means 22 prevents the well fluid from bypassing the desired flow path provided through the bore of outer housing 16.

The landing and locking means for the outer assembly or housing 16 is quite similar to that described in connection with Fig. 2, and operates in an exactly similar manner. The aforesaid means is operated to retrievably lock the outer housing 16 at a predetermined location in the tubing.

In Fig. 4, a construction somewhat different from that of Fig. 2 is used for the orifice head assembly. In Fig. 4, the inner housing or orifice head assembly 31^1 is again a member separate from outer housing 16, and is retrievably fastened in position in such outer housing. The substantially cylindrical main body portion 55^1 of orifice head assembly 31^1 is thickened and the prong-like tubular extension 57 (of Fig. 2) is omitted. The lower end of body portion 55^1 seats in the running neck 40 of the outer housing 16, and this body portion of the assembly 31^1 carries a pair of O-rings 33, to provide a seal between the outer surface of this body and the inner wall of the running neck 40 of outer housing 16.

The body portion 55^1 of orifice head assembly 31^1 terminates a short distance below the O-rings 33, in a plane substantially in alignment with the lower end of running neck 40, i.e., substantially in alignment with the junction of this running neck and the lower portion of housing 16. The body portion 55^1 of assembly 31^1 is provided with a central (axial) longitudinal bore 35 which communicates at its lower end with the longitudinal bore of outer housing 16. Bore 35 provides a fluid flow passage through the body 55^1 of the orifice head assembly. Fluid from the single producing zone, which flows vertically upward through the longitudinal bore in outer housing 16, flows upwardly in bore or passage 35. Bore 35 extends throughout the entire length of body portion 55^1 and the upper end of this bore opens into the lower end of a sleeve member 75 which is threadedly secured to the upper end of body 55^1. At the upper end of sleeve 75, there is mounted a replaceable choke 37 having a carbide-faced throat 60. Choke 37, through which all of the fluid from the producing zone passes, controls the rate of flow of this fluid. Choke 37, whose throat or passage 60 extends axially of sleeve 75 is held in position at the upper end of sleeve 75 by means of a threaded nut 61, just as in Fig. 2.

The structure for retrievably fastening the orifice head assembly 31^1 in position in the outer housing 16, i.e., seated in running neck 40 of such outer housing, is exactly the same as has previously been described in connection with Fig. 2, and includes the collet 69, the locking sleeve 73, etc. Such description will not be repeated here.

The bottom-hole choke of Fig. 4 has several advantages, as compared to other chokes of this general category. One of these is the ease of changing the choke means or bean 37. More particularly, running and pulling the orifice head assembly 31^1 of this invention is faster, more certain, and much simpler than running and pulling the chokebean-carrying mandrels previously used as bottom-hole chokes. To change the choke in prior devices, it is necessary to pull the entire tool; with the tool of this invention, only the orifice head 31^1 is pulled and reset, the outer housing 16 remaining in position in the hole. The construction of the present invention also substantially eliminates damage to plastic-coated tubing, since nothing which contacts the tubing need be pulled in order to change the choke.

Another advantage of the bottom-hole choke of this invention is its longer life. Since

a much smaller choke bean is used, there can be economically used (at 37) an extremely hard bean, which resists abrasion much better than the larger, softer beans used in conventional devices.

Yet another advantage is that running a conventional bottom-hole choke through liquid creates a problem of liquid bypass, which problem is not present in the Fig. 4 device.

The outer housing 16 in Fig. 4 (as in Fig. 2) has been stated to be a so-called "Otis Type S". However, it can be an "Otis Type J" mandrel or an "Otis Type B" mandrel. The orifice head assembly 31^1 can be run and locked in all of these mandrels.

WHAT WE CLAIM IS:—

1. A well-flow control device adapted to be positioned in well tubing for controlling the flow of a fluid into the tubing from a producing formation, comprising an outer housing having an opening for communication with the interior of said tubing means carried by the housing for retrievably locking the same at a predetermined location in the tubing, packing means for closing the annular space between the housing and tubing above said opening, said housing having an internal flow channel extending upwardly from its opening; an inner housing having an internal fluid flow passage for communication with said flow channel and with the interior of said tubing above said packing means; means carried by the inner housing for retrievably fastening the same in position in said outer housing, but allowing the withdrawal of the inner housing without the device from the well.

2. A device according to Claim 1 wherein the inner housing provides choke means located in the fluid flow passage.

3. A device according to Claim 2, wherein the choke means is positioned at the top of the inner housing, with the passage of the choke means extending longitudinally of the fluid flow passage.

4. A device according to any of the preceding Claims wherein the choke means is removably secured in said inner housing.

5. A device according to any of the preceding Claims wherein the opening is across the lower end of the outer housing.

6. A device according to any of Claims 1 to 4 wherein the opening in the outer housing is a side port.

7. A device according to Claim 6, wherein the outer housing side port comprises at least one narrow elongated slot in the housing wall, the width dimension of said slot being less than the diameter of the passage in the choke means.

8. A device adapted to be positioned in well tubing for controlling the flow of fluids into the tubing from a plurality of producing formations, comprising an outer housing having a side port for communication with the interior of said tubing; means carried by the housing for retrievably locking the same at a predetermined location in the tubing, packing means for closing the annular space between the housing and tubing above and below said port, said housing having a first internal flow channel extending upwardly from its side port and a second internal flow channel for upward fluid flow from beneath the packing means which is below said port; an inner housing having two internal fluid flow passages for communication respectively with said first and second flow channels, both of said flow passages communicating also with the interior of said tubing above the packing means which is above said port; means carried by the inner housing for retrievably fastening the same in position in said outer housing but allowing the withdrawal of the inner housing without the tool from the well.

9. A device according to Claim 8 wherein the inner housing provides choke means located in at least one of the fluid flow passages.

10. A device according to Claim 9 wherein the choke means or each of them is positioned at the top of the inner housing, with the passage of the choke means or each of them extending longitudinally of the fluid flow passage in which the choke means is located.

11. A device according to Claim 10 wherein the outer housing side port comprises at least one narrow elongated slot in the housing wall, the width dimension of said slot being less than the diameter of the passage of the choke means communicating with said slot.

12. A device according to any of Claims 9 to 11 wherein in the case when choke means are provided in each of the fluid-flow channels of the inner housing, the two choke means are disposed parallel to one another.

13. A device according to Claim 12, wherein the two choke means are separately removably secured in said inner housing.

14. A device according to any of Claims 8 to 13, wherein a resilient check valve member is provided in each of said channels of the iner housing for preventing downward fluid flow therein.

15. A device according to any of Claims 8 to 14, wherein the outer housing has a lower side port located below the packing means which is below the first-mentioned side port, said lower side port communicating with the interior of said tubing and with said second flow channel of the outer housing.

16. A device according to Claim 15, wherein the outer housing lower side ports comprises at least one narrow elongated slot in the housing wall, the width dimension of the slot being less than the diameter of the

passage in any choke means communicating with the slot.

17. A device according to Claim 15 or 16 wherein the annular space between the outer housing and the inner housing above said lower side port is closed by packing means.

18. A flow control device, comprising a main flow control device and an auxiliary flow control device which can be removed from the main flow control device without removing the latter from the well, for a well flow conductor having a longitudinal flow passage and a first lateral port communicating with the flow passage intermediate the ends thereof, the main flow control device including: an elongated mandrel positioned in the well flow conductor and provided with an internal flow passage for communicating at its upper end with the flow passage in the well flow conductor and with a second lateral port intermediate the ends of the mandrel for communicating with the exterior of the mandrel and said internal flow passage and with said first lateral port; seal means carried by the mandrel for sealing between the well flow conductor and the mandrel below said lateral ports, said mandrel having an aperture for communicating with the flow passage of the well flow conductor below the seal means; means carried by the mandrel permitting flow in one direction only into the internal flow passage of the mandrel through said second lateral port and said aperture; the auxiliary flow control device being releasably securable to the upper end of the mandrel and having means extending into the said internal flow passage providing with said internal flow passage, when the auxiliary flow control device is secured to the main flow control device, a first flow passage communicating with said second lateral port of the mandrel and opening upwardly into the well flow conductor above said first lateral port and providing a second flow passage communicating with said aperture and opening upwardly into the well flow conductor.

19. A main flow control device according to Claim 18 wherein seal means is provided on said mandrel for sealing between the mandrel and the well flow conductor above said ports.

20. A main flow control device according to Claim 19 wherein means are carried by the mandrel for releasably securing the mandrel in the well flow conductor and wherein the auxiliary flow control device has means in each of said first and second flow passages providing restricted orifices of predetermined relative sizes.

21. A main flow control device, according to Claim 20 wherein said auxiliary flow control device comprises a tube extension telescopable into said mandrel and having its lower end communicating with the aperture of the mandrel.

22. A main flow control device, according to Claim 21 wherein seal means are provided between the mandrel and the tube extension disposed between said second lateral port and the aperture of the mandrel.

23. A main flow control device, according to any of Claims 18 to 22 wherein the mandrel is provided with a downwardly facing shoulder at the upper end thereof, the auxiliary flow control device having means for engaging the downwardly facing shoulder to releasably secure the auxiliary flow control device to the mandrel.

24. A main flow control device according to Claim 23 wherein a lock means is provided on the auxiliary flow control device for holding the releasable means against disengagement from the downwardly facing shoulder.

25. A main flow control device according to any of Claims 21 to 24 wherein said auxiliary flow control device has a body provided with a pair of upwardly opening flow passages, one of said passages communicating with said second lateral port; and the other of said passages of the body communicating with said aperture.

26. A flow control device substantially as herein described with reference to Figures 1, 2A, 2B, 2C, 2D, and 3 or Figures 4A, 4B, 4C, and 4D of the accompanying drawings.

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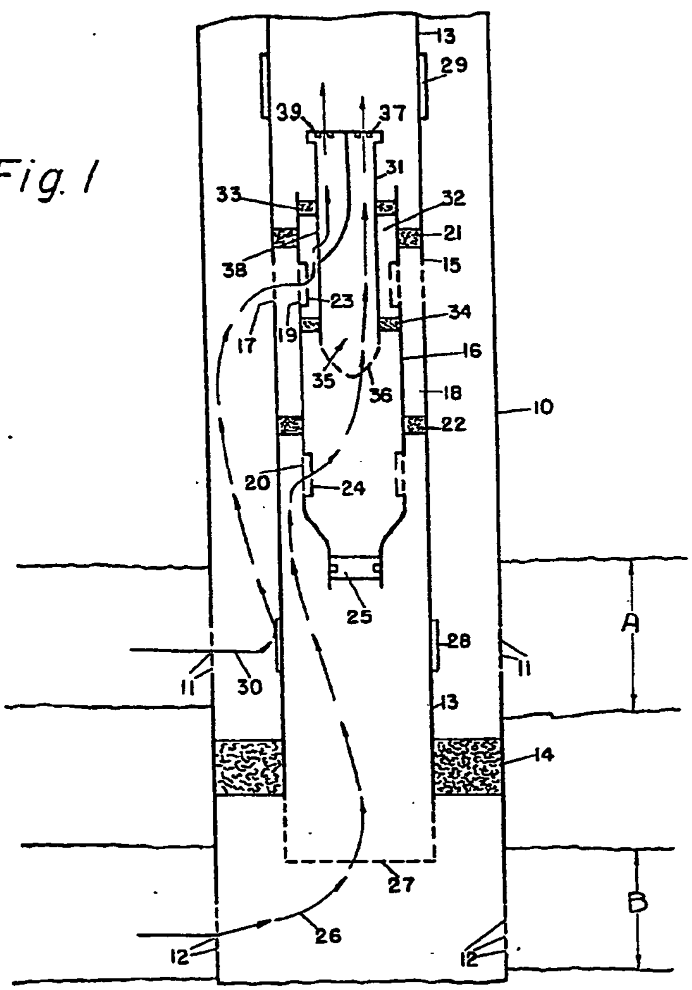
Fig. 1



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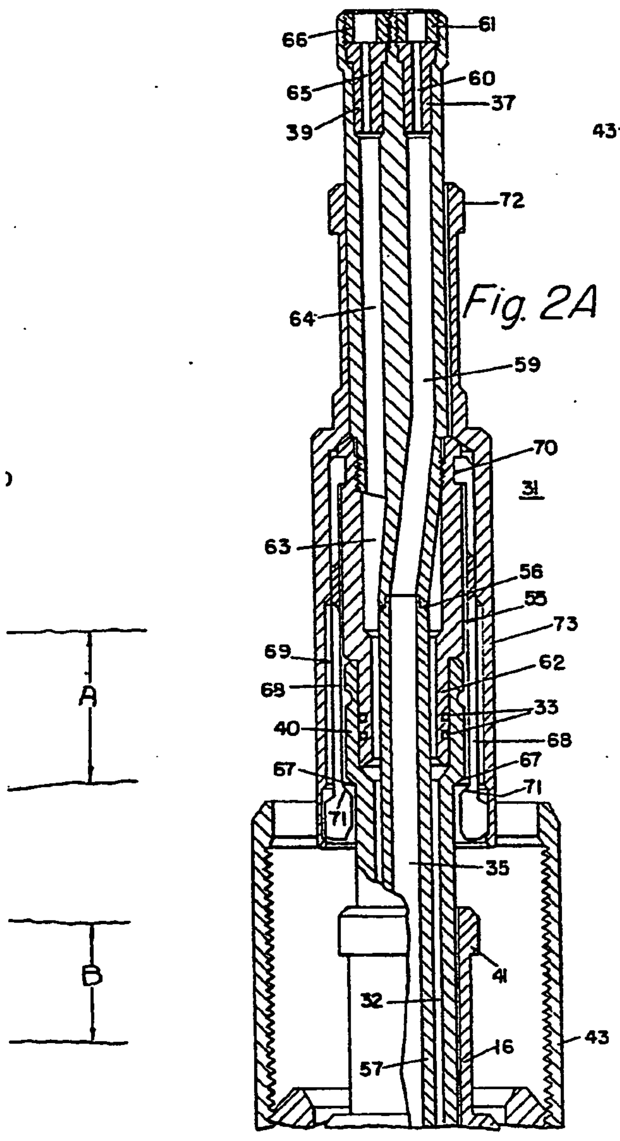

Fig. 2A

Fig. 2B

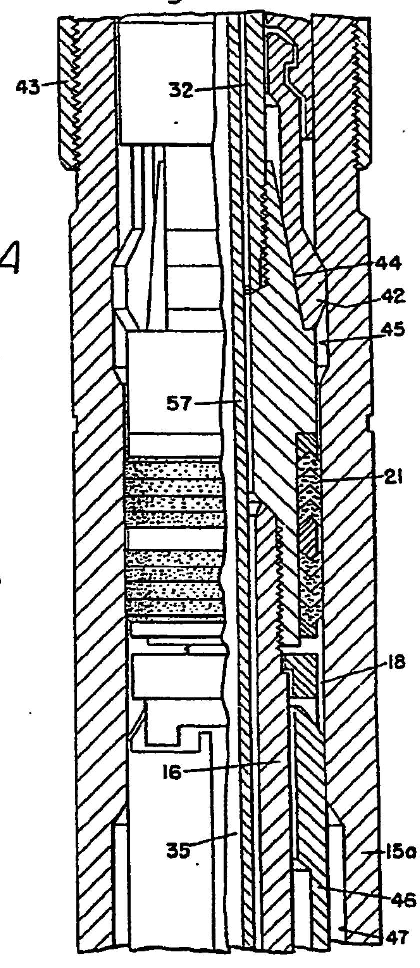

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Fig. 1

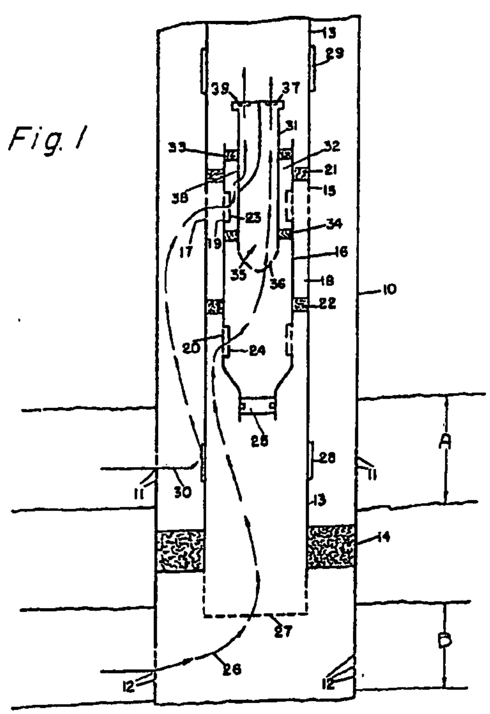


Fig. 2A

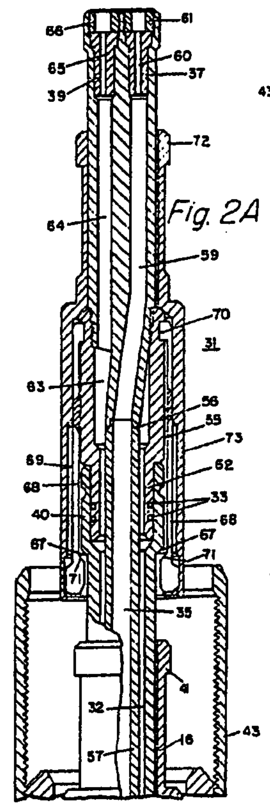
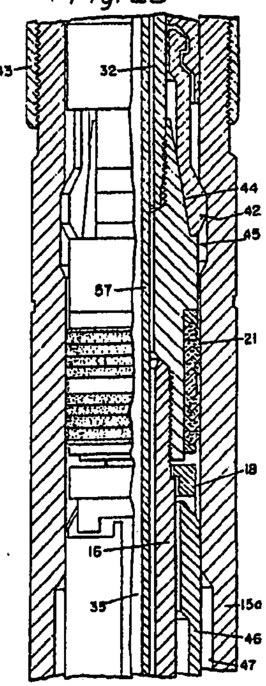


Fig. 2B



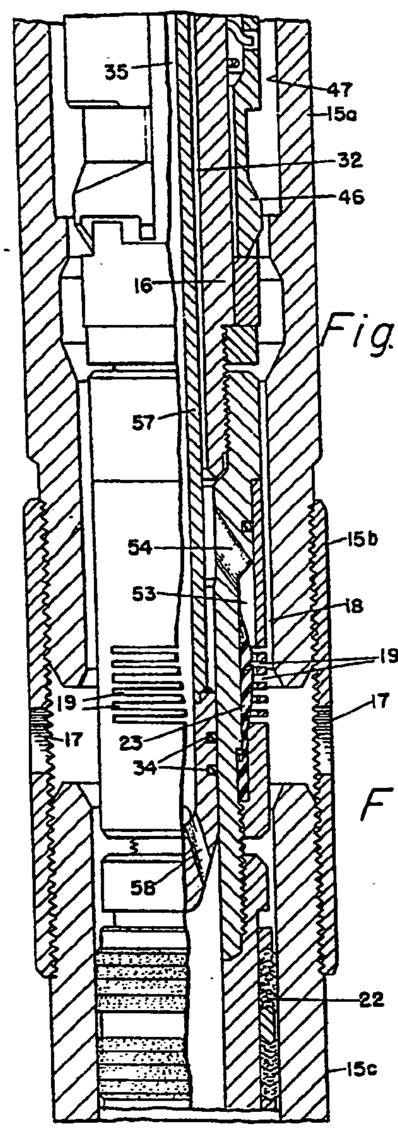

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Fig.2C

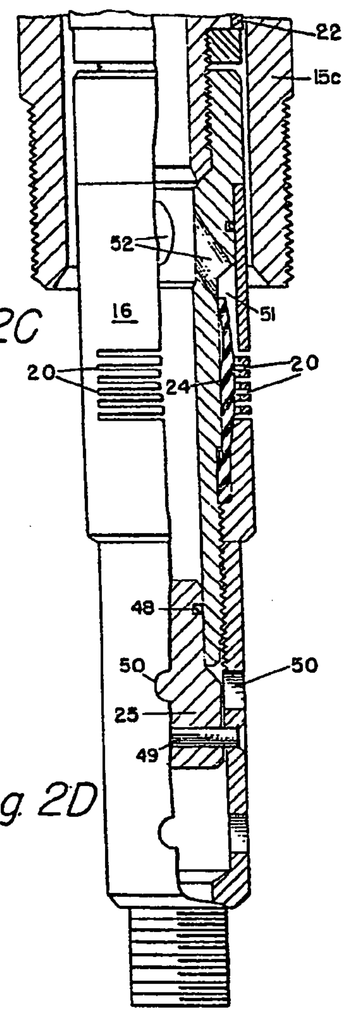
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Fig. 2D

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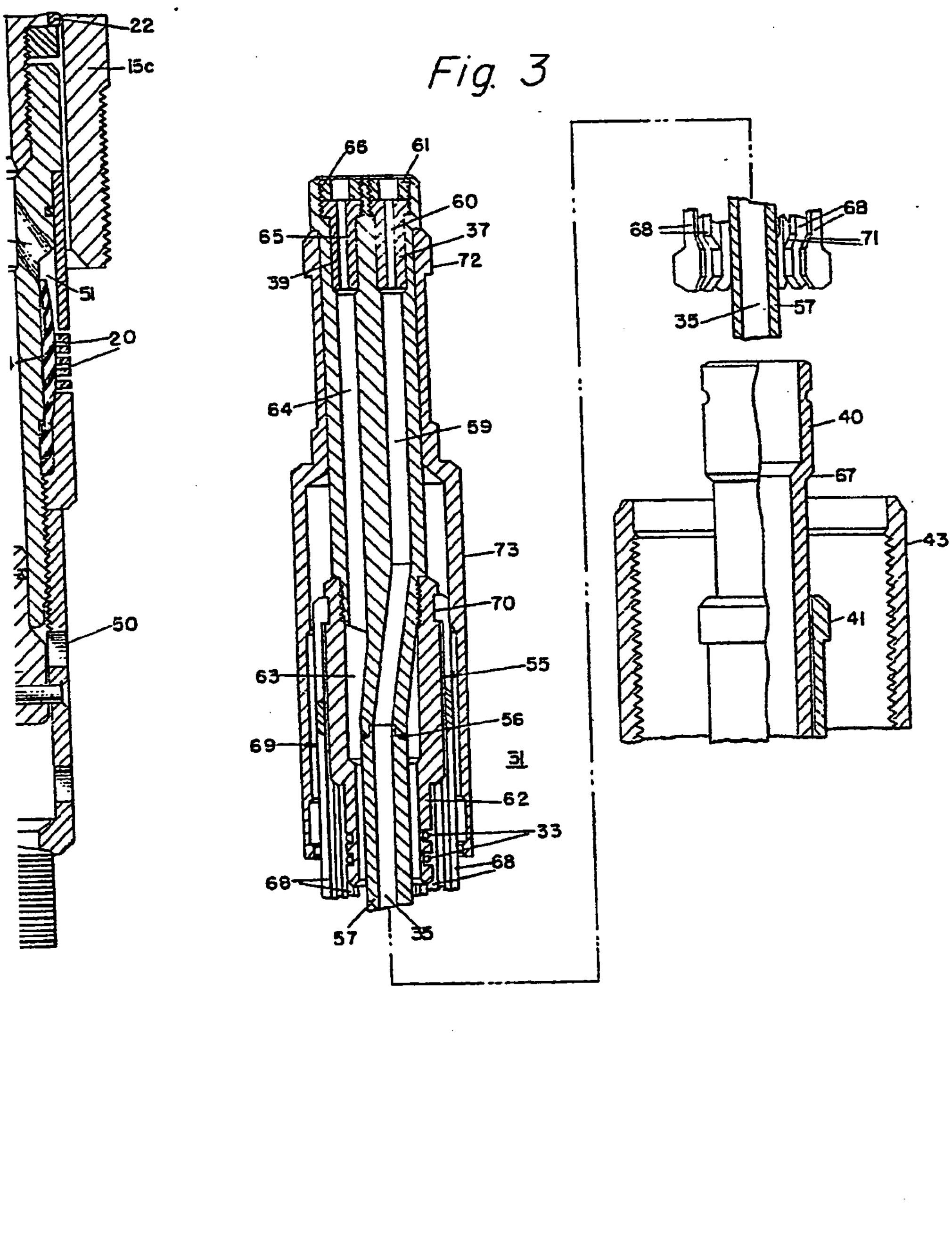

Fig. 3

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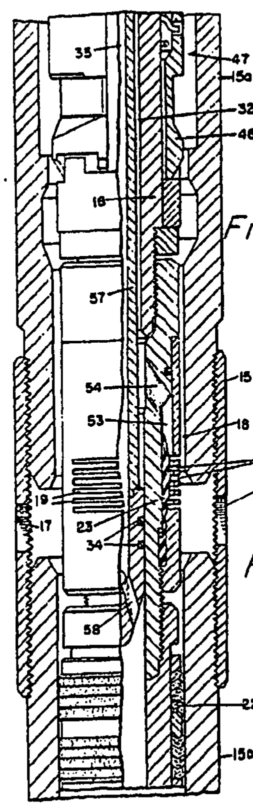

Fig2C

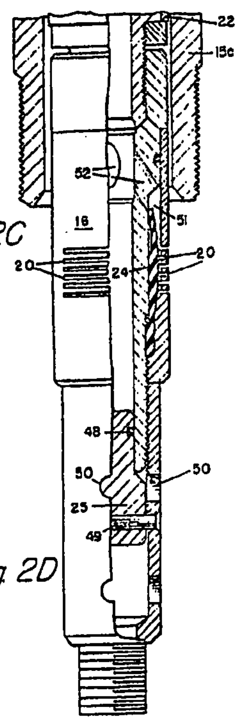

Fig 2D

Fig. 3

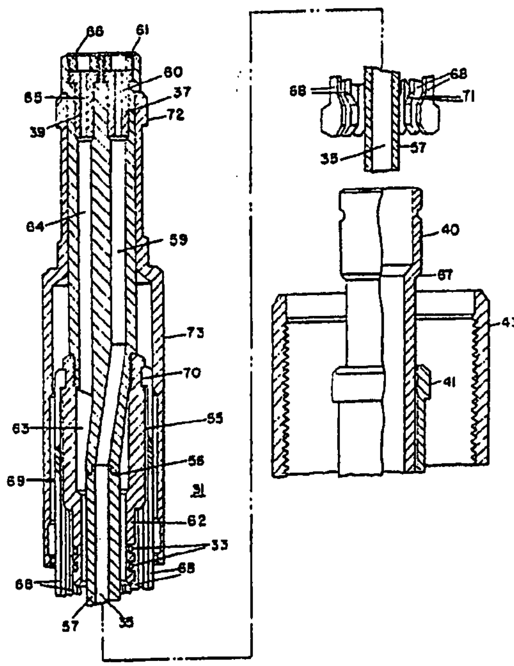

Fig. 4A

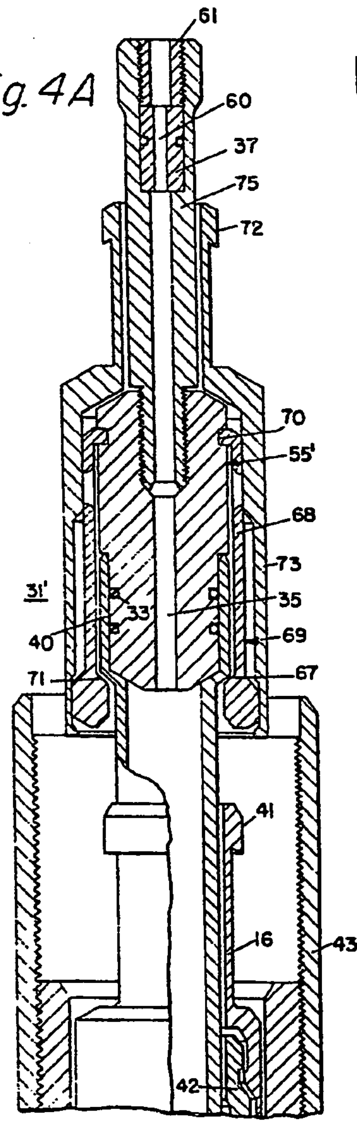

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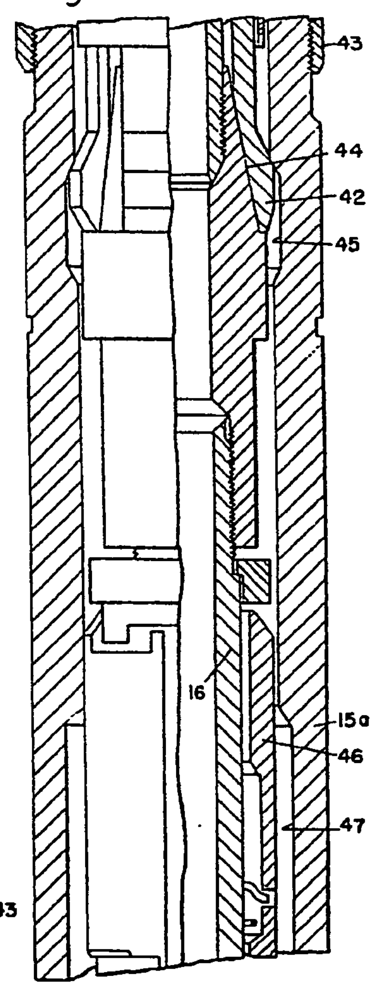
Fig. 4B



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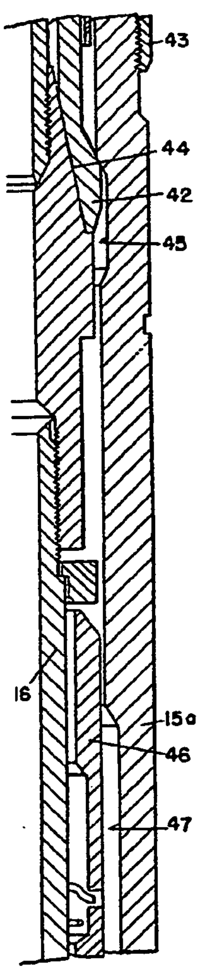

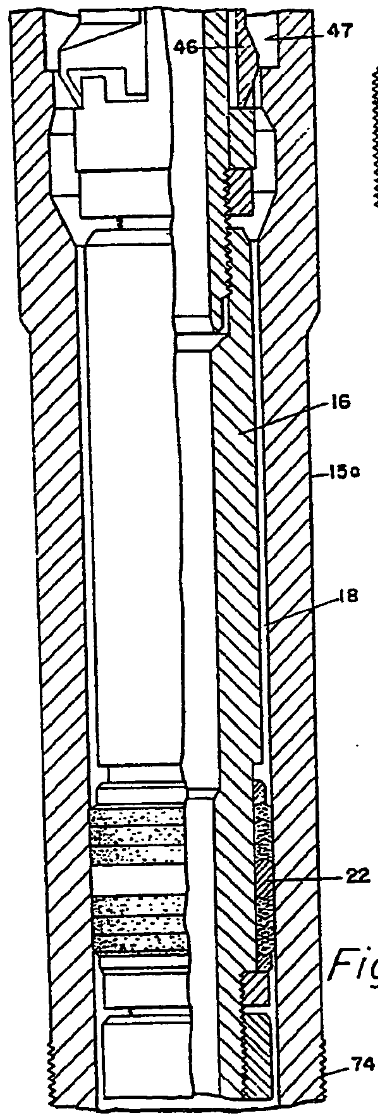

Fig.4C

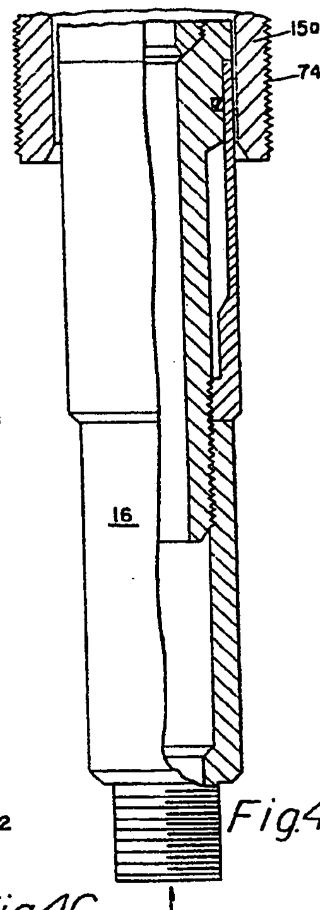

Fig.4D

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Sheets 5 & 6

Fig. 4A

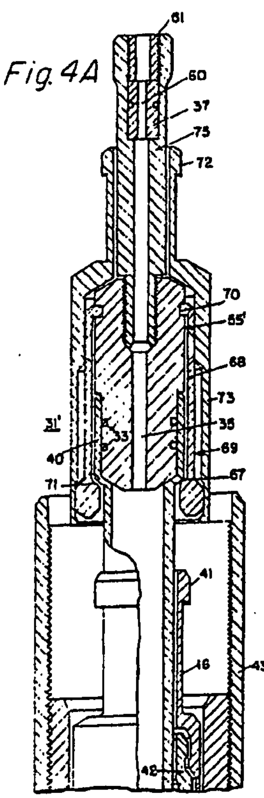
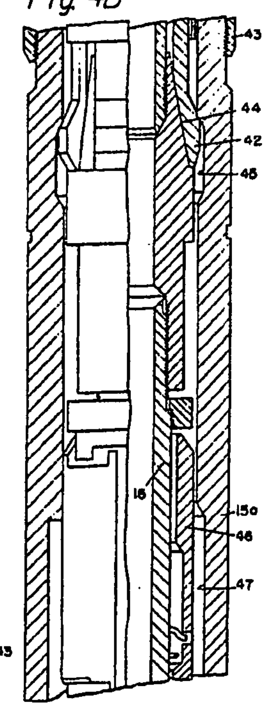


Fig. 4B



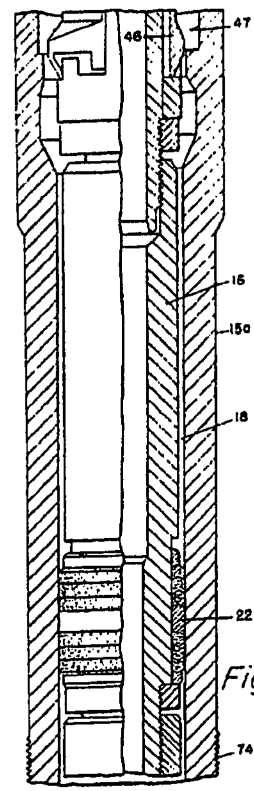


Fig 4C

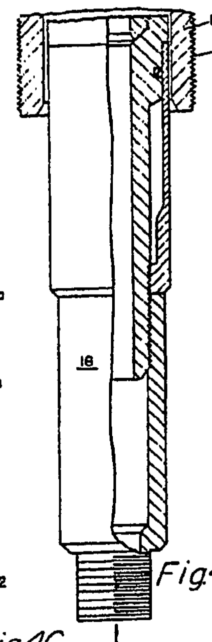


Fig 4D

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